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AUTHOR	Sullivan, Dennis
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ABSTRACT

Because the Navy needs tools to assess the personnel implications of proposed equipment and system designs, a literature search was conducted in 1978 to determine how hardware design engineers perceive the relationships between system design characteristics and the skills of the system operator and maintenance personnel. Recent studies conducted by the human resources research community were reviewed, especially research on the design process and skill information needs of designers, job performance, the analysis and measurement of skills, and the presentation of human resources information. It was found that engineers were responsive to human resources constraints when such constraints were presented as design requirements, but that they consistently ranked human resources data as less important than other aspects of system design. This publication presents the literature review and recommends that, in defining the techniques needed to communicate human resources data to design engineers, research be directed toward developing a better understanding of how engineers perceive the relationship between design characteristics and resulting skill implications, and that specific operational definitions of skills applicable to Navy ratings and pay grades be developed in terms and formats readily understandable to and directly usable by hardware designers. A 46-item bibliography is provided. (ESR)

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SYSTEM DESIGN CHARACTERISTICS AND USER SKILLS: A LITERATURE REVIEW

Dennis Sullivan
Hughes Aircraft Company
Fullerton, California 92634

Reviewed by
E. A. Koehler

Released by
Richard C. Sorenson

Navy Personnel Research and Development Center
San Diego, California 92152

FOREWORD

This effort was conducted under subproject Z1170-PN.05, Reducing Manpower Costs Through Better System Design, and was sponsored by the Deputy Chief of Naval Operations (Manpower, Personnel, and Training) (OP-01). The objective of the subproject is to develop techniques for analyzing hardware/software/personnel trade-offs at all stages of system design. The objective of the literature review reported here was to determine how hardware design engineers perceive the relationships between system design characteristics and skills of system operator and maintenance personnel.

The literature review was conducted in 1978 and subsequently used to prepare a draft version of an engineer's guide titled "Designing for Human Skills in Navy Electronic Systems." Further development of this guide was abandoned in favor of a related guide study, resulting in publication of <u>An Engineer's Guide to the Use of Human Resources in Electronic Systems Design</u> (NPRDC TN 79-8) and an evaluation of that guide (NPRDC SR 81-3). The literature review is being documented at this time so that it can be distributed to the research community.

The contracting officer's techical representative was Mr. Ernest A. Koehler.

RICHARD C. SORENSON
Director of Programs

SUMMARY

Problem

As new man-machine systems are developed for the Navy, the demand for highly qualified and skilled personnel to operate and maintain them increases. This increasing demand requires more efficient utilization of personnel at a time when the Navy's supply of manpower is limited, especially at the journeyman skill levels required for many system operator and technician ratings. Consequently, the requirements for such skilled personnel must be carefully considered in weighing the assets and liabilities of proposed equipment and system designs. Since competing designs are normally compared by the hardware development community during trade-off studies, tools are needed to assess the personnel implications of designs being considered.

Objective

The objective of this effort was to determine how hardware design engineers perceive the relationships between system design characteristics and skills of system operator and maintenance personnel.

Approach

Recent studies conducted by the human resources research community were reviewed. Special attention was directed toward research conducted on (1) the design process and skill information needs of designers, (2) job performance, (3) the analysis and measurement of skills, and (4) the presentation of human resources information.

Findings

1. Engineers were responsive to human resources constraints when such constraints were presented as design requirements.

2. The engineer's design is influenced by the amount of human resources data available and when, in the design cycle, it is presented.

3. Engineers responded more positively to human resources requirements when they were imposed as quantity constraints rather than skill level constraints.

4. The trade-off process in systems design depends on the personal styles and judgments of the engineers.

5. Engineers consistently ranked human resources data as less important than other aspects of system design.

6. The design engineers' lack of concern for human resources data derives partly from their education and experience, and partly from the inappropriateness of the data itself and its presentation.

Conclusions

1. Although the magnitude of the problem of communicating human resources data to design engineers is well recognized, its solution is not clearly definable.

2. The types of data required for communicating human resources information to engineers are not readily identifiable.

Recommendations

1. In defining the techniques needed to communicate human resources data to design engineers, research should be directed toward developing a better understanding of how engineers perceive the relationship between design characteristics and resulting skills implications.

2. Specific operational definitions of skills applicable to Navy ratings and pay grades operating and maintaining hardware systems should be developed. Such operational definitions should be in terms and formats readily understandable to and directly usable by the hardware designers.

CONTENTS

INTRODUCTION

Problem and Background

Manpower has become the most expensive component in the Navy's inventory. As newer, more advanced systems are developed, even more highly qualified and skilled personnel will be needed. As with any limited resource, increasing demands will necessitate more efficient utilization, adding two considerations to the design of new systems: personnel numbers and skill levels.

The number of personnel required to operate and maintain a system is somewhat independent of the system's level of automation because increased automation reduces operator needs, but increases maintenance requirements. System efficiency is achieved by judiciously trading off the degree of system automation with the skill levels operator and maintenance personnel require to maintain the system in an operational state. Personnel characteristics required to operate the system at a criterion level of performance may differ substantially from those required to maintain and support the system. Therefore, more efficient demands on the Navy's personnel resources can be made by making more effective trade-offs during the design of the system.

If skill is considered as a commodity obtained by applying a process--training--to a resource--aptitude--in return for whatever investment is required, then skill may be regarded as capital (Schultz, 1961) that can be traded against the other, less abstract forms of capital employed in system development. Models to quantify skill in the economic sense (Tinbergen & Bos, 1964; Davis & Pinto, 1975) will enable the designer to consider personnel skill simply as a multidimensional equipment parameter if a functional relationship can be established between system attributes and required personnel skills.

The importance of personnel skills to overall system effectiveness is presently receiving considerable attention in system design and development, because the acquisition, development, and retention of human resources contribute greatly to the system life cycle costs. Yet, as emphasized by Lintz, Loy, Hopper, and Potempa (1973), personnel requirements are often introduced late--or not at all--into the system design and development process, for various reasons:

1. Lack of effectively quantified data for use early in the design trade-off stages of system development.

2. Lack of a convenient vehicle for delivering these data to the user in a readily usable form.

3. The limited communications between the many specialists involved in making system decisions.

The point at which inputs regarding personnel skill are introduced into system design is critical. Askren (1973) reported that the preferred point of entry is during the period in which system design trade-off decisions are made. This period is also a good time for effective communications between the engineering and human factors specialists.

Three interrelated problems appear to be responsible for personnel skills information being ignored so often. First, definitions of skill are vague and inconsistent. Second, the data are unclear and difficult to translate into engineering or design requirements. The third, and most important, problem is the lack of concrete personnel skill data applicable to the design and development of Navy systems.

Objective

The objective of this effort was to determine how hardware design engineers perceive the relationships between system design characteristics and skills of system operator and maintenance personnel.

APPROACH

Studies conducted by the human resources research community were reviewed. As the literature search progressed, it became evident that four apparently disparate research areas were in fact directly related to the areas being addressed:

1. Research conducted by the Air Force and other agencies on the design process and the information needs of design personnel.

2. Research describing job performance.

3. Research conducted on the analysis and measurement of skills.

4. Research regarding the presentation of human resources information.

LITERATURE SEARCH

Impact of Human Factors Data on Designs and Designers

Meister, Sullivan, and Askren (1968) found that "manpower quantity and personnel skill constraint data impact the equipment configuration." This finding, which was based on detailed case studies of the design process presented to a number of skilled engineers, supported previous research regarding information utilization and the design process conducted by Meister and his associates (e.g., Meister & Farr, 1967; Meister & Sullivan, 1967), and others (e.g., Eastman, 1968; Forsythe, 1969). In a follow-on study, Meister, Sullivan, Finley, and Askren (1969a) found that "the amount and timing of human resources data inputs do exercise some influence on the engineers' design." They went on to state that the "type of requirement imposed (skill level versus quantity constraints) made a difference to the engineers." Building upon the results of the previously cited study, Meister, Sullivan, Finley, and Askren (1969b) examined the concepts of manpower and its component parts (skill, number of people, experience, etc.) as they related to system/equipment design of the same group of engineers. In their summary, they state that:

> The engineer relates a number of design concepts and characteristics such as test points, internal components, checkout and troubleshooting procedures, and type of test equipment required to the skill level of the maintenance technician. . . . The engineer's concept of skill level is more performance-oriented than that described by Air Force Specialty Code designators.

Askren and his associates concluded that engineers and managers resist considering man, with his various attributes and costs, as a hardware design constraint (Askren, 1976). The hypothesis was established that manpower-related factors would be acceptable to engineers and management as a "tiebreaker when all engineering factors are equal"

(Askren, 1976). For this concept to become operational, the design process itself had to be examined, and a new way of influencing the design process established. This gave rise to the series of studies by Askren and his associates begun in 1970 (e.g., Lintz, Askren, & Lott, 1971; Askren & Korkan, 1971; Askren, Korkan, & Watts, 1973; and Whalen & Askren, 1974).

Lintz et al. (1971) found a negative correlation (-.32) between utilization of human resources (HR) data by design engineers and experience (see Askren, 1973). They also found that HR data related to costs and numbers were considered almost three times more valuable than data related to "skill type" or personnel availability (see also Whalen & Askren, 1974). In their conclusions, Lintz et al. (1971) state that design engineers will include HR data in engineering design trade studies and "that the trade-off process is very much dependent on the personal style and judgments of the engineer" (Whalen & Askren, 1974).

In a summary of work sponsored by the Air Force between 1968 and 1973, Askren (1973) stated that, before HR data could be effective, it would be necessary to provide data to the engineer regarding the effect on man of "choice point alternatives" in the system design process. Askren and Lintz (1975) contradicted this statement in their conclusions regarding the same work. Their engineer subjects did not agree on the value of any trade-off study parameter, including HR data. None of their subjects ever requested HR data for use in solving the problems presented. Finally, no distinct impact for incorporating HR data could be determined.

Whalen and Askren (1974) attempted to identify and classify those aspects of the design trade study process that have "high potential impact on human resource requirements." They generated the hypothesis that, "the greater the technological disparity between trade study design alternatives, the greater will be the potential impact of the design decision on human resource requirements." When engineers were asked to judge the "technological disparity" in trade studies that had already been judged to be "high" or "low" in their impact on human resources, this hypothesis was supported.

In a related study, Askren and his associates explored methods for describing and influencing the design process. Askren and Korkan (1971) conducted an extensive review and analysis of the literature related to the description of human decision processes, and developed the design option decision tree (DODT) concept as a means to predetermine the design options available to the engineer as he progresses through a design problem. The rationale was that, to the extent that design decisions could be determined in advance, the relevant types of HR data could be acquired and presented to the engineer before he made his decisions. The DODT was tried as a "graphic means of depicting the sequence of engineering decisions required for resolution of a design problem," and was judged by eight engineering subjects to be a "feasible and valid method for anticipating and describing system design trade-offs" (Askren & Korkan, 1971).

Subsequently, Askren and his associates set out to "explore the feasibility of developing design option decision trees to a level of detail that shows hardware involved in maintenance-operations, and to measure the sensitivity of different types of human resources data to different design trade-off problems depicted in these trees" (Askren & Korkan, 1974). In summarizing the results of that effort, Askren (1976) states:

> It was found that DODTs can be developed to the maintenance level of detail. It was also found that the factors of training and experience, amount of maintenance time, and ease of maintenance were most affected by choice of design options in the trade-off problems.

Whalen and Askren (1974), Potter, Korkan, and Dieterly (1975b), and Potempa, Lintz, and Luckew (1975) all explored means for determining the impact of design decisions on various HR parameters. Potter, Korkan and Dieterly (1975a) concluded that no satisfactory technique for measuring the impact of projected technological developments on HR was available. However, in a summary of the Whalen and Askren (1974) study, Asken (1976) found that:

> (Air Force maintenance technicians) can make reasonably accurate estimates of the amount of time, the Air Force occupational specialty, the level of technical skill, and the number of personnel needed to perform field maintenance tasks.

These conclusions are loosely supported by the original study. Potempa et al. (1975) developed some models that correlate system/equipment design characteristics and certain personnel characteristics (e.g., aptitude, education, etc.) with performance during the training course and on the job. The inputs to these models were the judgments, ratings, and rankings by students and instructors for training course performance, and those of maintenance supervisors for job performance. They concluded that HR data could be used alone to predict school performance, and that HR data (including school performance) and maintenance-related design characteristics could be used to predict job performance. All of these studies have, however, attacked the problem from the same viewpoint, and none give enough information about the impact of the technological aspects of a design on the man portion of a man-machine system, or the design engineer himself and his modes of operation. What Askren and his associates appear to have done is to develop certain methods and techniques for describing the design process (e.g., the DODT). They also developed methods for acquiring certain kinds of HR data related to maintenance from personnel who maintain existing systems/equipment with functional characteristics similar to those of the system being designed.

The first of these methods is predicated on the view that design is a logical, decision-making process in which the designer "methodically" makes a series of design choices (Askren, 1976). The second, which follows from the first, is that the data for the decision process must be gathered in a manner that is responsive to the specific alternatives at each decision point. Inherent to this concept is the model of the supplier of HR data as an informed ally of the designer, or even as an active participating member of the design team. This concept, which the authors wholeheartedly support, is all too rare.

Another concept of the design process is that, with all of the pressures, constraints, and technological problems that must be resolved in the press of conceptualizing, designing, documenting, and selling systems/equipment, those system aspects dealing with man are given rather low priority. In the studies by Meister and his associates (1968,

1969a & 1969b), Lintz et al. (1971), and Askren and Lintz (1975), HR-type data are consistently ranked as less important than data related to "harder" aspects of the system/equipment design. There are probably many reasons for this lack of concern for the personnel who operate and maintain the systems. There are strong indications, however, that one reason is the inability of HR specialists to select and present information to meet the input requirements of the engineers who have differing education and experience. Askren (1976) asked the question: "Which process (approach to design) will a given engineer follow for a given design?" He answered by stating:

> The answer seems dependent on a number of factors such as the training of the engineer, his personal style, the nature of the design problem, the time available to complete the design task, and company and management design philosophy.

The previously cited studies (e.g., Meister et al., 1967-1970; Askren & Korkan, 1971, 1974; Lintz et al., 1971; Lintz, Lay, Brock, & Potempa, 1973) have led to several attempts to develop and format human factors (HF) and HR data into handbooks (Devoe, 1963; Meister & Sullivan, 1969; Parker & West, 1973; Reed, Snyder, Baran, Loy, & Curtin, 1975; VanCott & Kinkade, 1972; Woodson, 1954, 1964). The fact that these efforts have not induced engineers to use HR data in their designs is attributable to several prominent factors. In the series of studies conducted for the Air Force's Human Resources Laboratory (reviewed in Askren, 1976), it was found that:

1. Engineers responded primarily to design inputs presented as specific design requirements.

2. Engineers will respond to manpower quantity skill level data presented in an understandable manner.

3. Data presented as design requirements had a stronger impact upon design engineer acceptance and subsequent performance than did data presented as information.

4. Certain maintenance design characteristics are perceived by design engineers as being more strongly affected by the skill level of maintenance personnel than are others.

5. Engineers and design managers were most likely to include HF or HR data as system inputs during design tradeoff studies. At that time, information related to

personnel costs and manpower quantities was given more "weight" than was that related to skill types, skill levels, or personnel availability.

The ineffectiveness of previous attempts to present personnel skill data and related manpower information to design engineers must be tied to two deficiencies of the HR data bases themselves: (1) skill is a relatively inexact concept in the behavioral sciences and (2) there are almost no data regarding the engineers' concept of skill.

Alternative Approaches to the Description/Definition of Personnel Skill

Fleishman's (1967) definition of skill as "the level of proficiency on a specific task or limited group of tasks" was used as a basis for this research effort because it is more closely related to the operational uses of the term than are those definitions that limit skill to psychomoter abilities (e.g., Dunnette, 1976). Skill must be considered in light of work performance (operations or maintenance) within the organizational environment provided by the Navy's missions.

Researchers interested in human learning have exerted significant efforts and time to understanding the nature of intelligence and other human abilities related to performance during learning and work. These efforts have produced an enormous volume of tests of "different" human abilities. (See Finley, Obermayer, Bertone, Meister, & Muckler, 1970, for a discussion of this research.)

In any type of research, including that involving the classification/analysis of human performance, investigators are prone to use taxonomic schemes. Taxonomies are usually developed by selecting and labeling instances of a class of objects or behaviors and arranging them according to various similiarities and differences between their individual properties or attributes. The most crucial problem in taxonomy development, of course, is the actual choice of the attributes forming the basis of the classification scheme.

Fleishman (1975) viewed any "system of classification as a tool to increase ability to interpret or predict some facet of human performance." He goes on to state:

> We can elect to develop a system of classification having utility for a limited area . . . , or we may look for a system from which a variety

14

> of applications may stem. . . . Where broad task classification systems are developed as autonomous structures, which are only some time later to be applied to other variables, the classification exercise is an integral step in the development of theory. The resultant system provides a consistent conceptual framework, the elements of which eventually are to be used in the interpretation or prediction of human performance.

Three interrelated approaches are available to describe and select concepts of skill or skill attributes that interact with equipment design: (1) an existing aptitude or trait system (e.g., Fleishman's set of psychomoter aptitudes), (2) task descriptive data (e.g., NOTAPS information), and (3) designers' own concepts of skills. Outcomes from any of these approaches must be related to their impact on specific dimensions of hardware and system design.

Meister and Mills (1970), in evaluating the alternative approaches available for the classification of human performance, state:

> Previous taxonomic practice has been to develop a a priori sic classification and to attempt to force-fit the behavioral phenomena into the existent classification scheme.

Four conceptual approaches to the description of tasks are described by Barret, Dambrot, and Smith (1975), and Fleishman (1975):

1. In the behavioral description approach, tasks categories are based on observations and descriptions of what individuals actually do while performing a task. The Position Analysis Questionnaire, wherein job and task performance are observed and rated by trained observers, is an example of this approach (McCormick, Jeanneret, & Mecham, 1972).

2. In the behavioral requirements approach, those behaviors assumed to be required to perform given tasks are catalogued. Although a number of efforts have been directed toward identifying and codifying the intellectual and physical processes by which tasks get accomplished, these efforts generally have been used to categorize behavior without any systematic effort at validation. The rationally established classification systems developed by Berliner, Angell, and Shearer (1974), Miller (1976), and Christensen and Mills (1967)

are examples of this approach. Barret and his associates (1975) found that the rationally formulated task taxonomic systems developed by using this approach fluctuate between describing tasks and their behavioral anteoedents. They state that this approach has "not yielded a standarized classification system with wide generalization or integrative power."

3. The ability requirements approach is defined by Fleishman (1975) as being similar in many respects to the behavioral requirements approach already described. He states that it differs "primarily in terms of concept derivation and level of description." He goes on to state that "the ability concepts are empirically derived through factor analytic studies and are treated as more basic units than the behavior functions." Fleishman expressed his belief that this approach can provide an integrative framework for understanding task performance under a variety of conditions. In a related effort, Barret et al. (1975) state that "task taxonomies, based on the abilities approach, have been effective in laboratory settings. Findings have not been validated in field studies."

4. Fleishman (1975) defined the task characteristics approach as "predicated on a definition that treats the task as a set of conditions that elicit performance. . . . Having adopted this point of view, appropriate descriptive terms are those that focus on the task per se. The assumption is made that tasks can be described and differentiated in terms of intrinsic, objective properties they may possess." An example of this approach is the work of Farina and Wheaton (1971), which uses scalar ratings to relate task characteristics to ability requirements.

In reviewing the utility of the various approaches to the classification/analysis of human performance, Meister (1971) states: "Indeed, it is conceivable that no universal taxonomy can be applied, because task descriptive needs vary from system to system." He further states: "The suitability of a task description depends on the purpose for which it is being developed."

Dunnette (1976) concludes:

> Studies of aptitudes and skills on the one hand and work performance on the other have apparently yielded two quite distinct taxonomic worlds--one based mostly on standardized test responses, the other based mostly on the study and description of actual work performance.

In seeking to link these two worlds, Dunnette suggests that the difference between them is based on (1) the level of molarity of the classification systems employed, and (2) whether the classification systems are empirical or inferential in nature. He states: "So far, no one has derived behavioral taxonomy midway between the world of work and the world of human attributes measured via standardized tests and inventories."

Such a taxonomy, which would be a useful framework for studying the designers' concept of skill, unfortunately, does not exist. However, the research does exist to suggest a method for achieving the goals of this study. If the design engineers' concepts of the term skill and its components, and the relationship between these concepts and various aspects of hardware design can be defined, then it should be possible to locate data on those concepts that engineers could use in the design process. Based on the literature reviewed herein, it appears that a combination of the last three approaches would be most favorable to the objectives of this research effort.

A review of the previous research related to engineers' understanding and use of HF or HR data in the analysis, development, and establishment of system/equipment design (e.g., Meister et al., 1967-1969; Reed et al., 1975; Lintz et al., 1971; Meister, 1976) reveals that the methods employed have been of three types. First, in the structured design exercise, or simulation, a design problem derived or selected by the researcher was presented to the individual engineer for solution. The major variables in these studies (e.g., Meister & Sullivan, 1967; Meister et al., 1968; Eastman, 1968; Lintz et al., 1971) were type and the presence (or absence) of HF or HR data made available to the engineer subjects.

In the second method, engineer subjects were presented with selected types of HF or HR data. Typically, this information had been extracted from existing HF or HR data documentation (see Meister & Farr, 1967; Rogers & Armstrong, 1977; Rogers & Pegden, 1977) or from proposed formulations of this type of information (see Meister & Sullivan; 1969; Meister, 1976). The variables in studies using this method were the types of information provided and the means by which they were presented to the user. Usually measurement consisted of assessing the users' preferences for alternative formats, and their ability to extract the "correct" information from the various types of data presentations.

In the third method, various groups of "experts" were asked about the importance of certain human-engineering or HR factors on system design or operation (see Whalen & Askren, 1974; Blanchard, 1975; Potempa et al., 1975). The bulk of the efforts employing this method have been conducted for the Air Force by Askren and his associates. They demonstrated that operational personnel (equipment operators and maintenance personnel) can estimate the impact of certain types of system/equipment characteristics on the numbers and types of personnel required (Potter et al., 1975b; Potempa et al., 1975; Whalen & Askren, 1974). They also showed that engineers have consistently limited their concepts of HF or HR data to those aspects that are important to their concepts of system/equipment operations or maintenance (Meister et al., 1969a, 1969b; Blanchard, 1975; Meister, 1976). In a separate area, McCormick and his associates (1972) employed the same method to assess the extent to which job designers use HR-type data.

Previous Design Guide Research

In summarizing his review of the Air Force's work on the use of HR data in design, Askren (1976) makes several points related to the nature and direction of the proposed effort. He states:

> The overriding finding throughout all of the research has been the feasibility and practicality of using human resources data as criteria in engineering design studies. Quantification of the data is possible. Engineers accept the data. Input points to the design process are available. And the quality of the human data is often as good as the quality of the engineering data, especially in early conceptual design studies.

A wide variety of human resources data were found to be useful criteria in design studies. This included such factors as manpower quantity, technician skill level, technician job speciality, personnel dollar cost, type and amount of training, task performance, time, job difficulty, and personnel turnover rate. The sixth study (Askren et al., 1973) found that the type of data relevant to a particular design problem is a function of the nature of the design studies. It is critical to provide the engineer with data that is most relevant.

These conclusions support the results reported by Meister and Farr (1967), and Meister and Sullivan (1969a, 1969b), and are expanded by the findings reported in Meister's 1976 study, which assessed the effectiveness, utility, and acceptability of the prototype HR data handbook developed by Reed et al. (1975). Meister found that the development and presentation of HF/HR data to design engineering personnel produced the following conclusions:

a. System development personnel can use the prototype handbook to make significantly more correct decisions than without the handbook. Engineers have greater confidence in decisions made with the prototype handbook than without it.

b. If one considers that a substantial percentage of participants viewed the prototype handbook as having utility and potential influence on design, the audience for this handbook is potentially large. Engineers had some difficulty recognizing the kinds of problems for which the prototype handbook was designed as ones they ordinarily encountered, but considered these problems to be realistic. Engineers consider their own data sources almost as good as the prototype handbook, but much less accessible.

c. Those who saw utility in the prototype handbook and are hence more likely to use it are more likely to have specialized jobs (e.g., human factors, maintainability, crew station design) than general design functions. Those who have worked on problems of the type dealt with by the prototype handbook tended to be more positive to that handbook and are therefore more likely to use it.

d. A number of improvements were recommended by assessment participants, including updating the data, simplifying the Master Index system, reducing verbiage in the tables and clarifying the implications of the prototype handbook data. These improvements are required to make the prototype handbook maximally useful.

The assessment was sufficiently positive to warrant continuing efforts to develop handbooks and/or data banks of HR data for use in the design of new systems and equipments.

Rogers and Armstrong (1977), in a study examining the use of human engineering standards (the most common of existing formats for transmitting HF/HR information to designers), concluded that: "Existing standards appear to have little effect on product design." The authors then went on to suggest that human engineering/HF standards could be enhanced if the following suggestions were adopted:

> 1. Eliminate the use of such terms as "whenever possible," "proper feel," "high torque," which are general in nature or ambiguous. If the requirement cannot be expressed in quantitative or more exacting terminology, do not include it or define it as only a guideline.
>
> 2. Present quantitative data in a manner consistent with designer preference (i.e., graphical or pictorial means first, followed by tabulations).
>
> 3. Eliminate inconsistencies in data within standards and between standards. The between standards differences could be reduced by the incorporation of all government-sponsored human factors standards into one single standard with applicable sections to cover individual agency needs.
>
> 4. Provide revisions and updating of standards in a more timely manner; to make current information available to the user. With the rapidly changing technology, yearly revisions would seem more appropriate than the two- to four-year revision cycle of the past.

These suggestions are probably just as relevant to the development of the proposed designs as to the standards that were the subject of the cited study.

A parallel study (Rogers & Pegden, 1977), which involved a detailed analysis of two existing government human engineering standards and the results of a survey of 65 designers and human engineering specialists, identified the major formatting and organizational problems that reduced the effectiveness of these standards:

1. Content.
2. Lack of graphic presentations.
3. Lack of adequate indexing systems.
4. Lack of clearly defined common terms.

These same problems had been identified earlier (Meister & Farr, 1967; Meister & Sullivan, 1968), and attempts were made to remedy them in documents developed by Meister and Sullivan (1969) and Reed et al. (1975). In both of these efforts, some attempts were made to identify the target audience for which these guides should be developed. Although these efforts were largely unsuccessful, it was recognized that all system design personnel do not need the same HR data, and that, they do not share the same information acquisition, storage, and retrieval organization or structure.

CONCLUSIONS

The magnitude of the problem of communicating HR data to design engineers is well recognized, but its solution is not clearly definable. Also, the types of data required for communicating human resources information to engineers are not readily identifiable. The following questions remain to answered:

1. Who will be the primary users of HR information? If they are the behavioral specialists who translate these data for other system development personnel, the audience for the information is small and highly specialized. If they are other system development personnel who use the information to translate the behavioral inputs directly into engineering terms, what is the role of the human factors specialist in systems development? Should the information be addressed to both types of audiences? Is it possible to present data for two such different user groups in the same format?

2. Is there a subset of system development personnel (e.g., engineering specialties, such as maintainance, crew system design, etc.) other than human factors specialists, to whom this type of information should be specifically directed? How broad should the targeted audience for this information be?

3. What kind of reaction signifies that the intended audience will in fact make use of this information? What does the developer expect the user to do with this kind of information?

4. What is the intended scope of the data to be presented? Although numerous data bases, hundreds of publications, and perhaps thousands of journal articles are available, much of this data are too vague and imprecise to be of value during the design engineering process.

RECOMMENDATIONS

1. In defining the techniques needed to communicate HR data to design engineers, research should be directed toward developing a better understanding of how engineers perceive the relationship between design characteristics and resulting skills implications.

2. Specific operational definitions of skills applicable to Navy ratings and pay grades operating and maintaining hardware systems should be developed. Such operational definitions should be in terms and formats readily understandable to and directly usable by the hardware designers.

22

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